

Educational Interventions to Improve Pharmacy Learners' Recognition and Management of Prescribing and Dispensing Errors: A Systematic Review of Performance Outcomes, Retention, and Transfer to Practice

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Abstract

To examine educational interventions addressing pharmacy learners' recognition and management of prescribing and dispensing errors, with particular attention to demonstrated performance, retention of learning, and transfer into clinical and pharmacy practice. A systematic review was conducted in accordance with PRISMA 2020. PubMed/MEDLINE, Scopus, and ERIC were searched for literature published from 2017 through 2025 using terms for pharmacy education, medication errors, prescribing, dispensing, simulation, order verification, and assessment. Thirty-eight unique records were screened; six reports underwent full-text review and four studies met the inclusion criteria. Data were extracted by outcome domain, assessment timing, and setting, and findings were synthesized narratively because of methodological and outcome heterogeneity. Four studies evaluated electronic medication-order verification, alert-based simulation, virtual medication verification, or sterile-compounding accuracy checking. The prescribing-focused studies reported improved performance or more appropriate responses under simulated conditions, although design differences limited cross-study comparison. The dispensing-focused study showed no improvement in first-attempt accuracy in the later cohort but better remediation performance. Evidence of long-term retention was limited, and no included study evaluated authentic workplace transfer. Simulation and electronic medication-verification activities can strengthen selected error-recognition and management tasks, but effects are task-specific and supported mainly by nonrandomized, simulation-based evidence. Future studies should incorporate delayed reassessment and authentic practice outcomes.

Keywords: Pharmacy education, Medication errors, Prescribing errors, Dispensing errors, Simulation-based education, Learning retention

Introduction

Medication safety depends on the identification and management of problems arising across prescribing, order verification, preparation, dispensing, administration, and subsequent monitoring. Pharmacy

learners must develop the capacity to recognize clinically consequential discrepancies, interpret available patient information, determine whether an apparent problem requires intervention, and communicate an appropriate response. These activities involve different combinations of therapeutic knowledge, technical accuracy, clinical reasoning, and professional judgment. Their educational assessment consequently requires greater specificity than a general measure of medication-safety awareness.

A systematic review of dispensing errors across pharmacy settings illustrates the continuing significance of dispensing accuracy while also demonstrating variability in how errors are defined, detected, and

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measured [1]. An international review of medication errors in community pharmacies similarly identifies the importance of examining error types, severity, and the circumstances under which errors occur [2]. Such practice-level evidence establishes the clinical context for pharmacy education but cannot independently demonstrate the effectiveness of a particular teaching intervention.

Educational interventions have increasingly incorporated virtual pharmacy environments, simulated prescriptions, clinical cases, electronic health records, feedback, and structured performance assessments. MyDispense, for example, permits learners to encounter dispensing scenarios in a simulated pharmacy environment. A scoping review identified applications involving dispensing skills, communication, decision-making, problem-solving, performance, and reflection [3]. These applications illustrate the breadth of simulation-based pharmacy education, although the presence of an educational activity does not establish improvement in every competency it addresses.

An important measurement issue arises when intervention evaluations prioritize learners' perceptions of their ability. A systematic review of simulation in clinical pharmacy education examined confidence across activities such as information gathering, counselling, communication, and clinical procedures [4]. Confidence can influence participation and willingness to undertake professional tasks, but it represents a different construct from independently assessed performance. A separate review comparing health-professions students' self-assessments with objective competence measures supports the need to use demonstrated competency as a principal educational endpoint [5].

This distinction has direct implications for medication-error education. A learner may feel more capable of identifying prescribing problems after completing a simulation yet still overlook an inappropriate dose, misinterpret a clinically relevant interaction, or reject an order that is safe but unfamiliar. Conversely, a learner may identify a discrepancy correctly without selecting an appropriate corrective action. Recognition and management should therefore be evaluated separately where the assessment permits, even when both contribute to the same medication-use decision.

Simulation-based medication-safety teaching also encompasses activities that assess broader knowledge, skills, and attitudes. Frenzel and colleagues evaluated root-cause-analysis simulations involving medication

errors in pharmacy settings and reported improvements in measured educational domains [6]. These findings demonstrate the potential educational contribution of structured simulation, while the particular assessment instruments and learning tasks determine which competencies the results establish.

The medication-use process provides an additional reason to distinguish educational outcomes carefully. Prescribing, order processing, dispensing, administration, and monitoring involve related but nonidentical responsibilities. A review of pharmacy education in medication-use process stewardship describes educational approaches spanning these activities and identifies the continuing need to align curricular content with professional responsibilities [7]. An intervention focused on medication reconciliation, for example, may develop transferable reasoning skills without directly assessing dispensing-error recognition. Similarly, an exercise involving error disclosure may evaluate communication following an incident without demonstrating improved detection of the original error.

For this review, prescribing-error recognition concerns the identification and interpretation of problems in a medication order, including inappropriate drug selection, dose, frequency, route, duration, duplication, contraindication, or other clinically relevant prescribing discrepancies. Dispensing-error recognition concerns the identification of discrepancies arising during prescription interpretation, product selection, preparation, labelling, accuracy checking, and supply. Management includes the response undertaken after identifying a potential problem, such as clinical clarification, correction, documentation, escalation, counselling, or confirmation that the intended medication can be supplied safely.

These definitions preserve the difference between detecting a possible problem and establishing that an actual error occurred. An assessment that rewards rejection of every unfamiliar order may overestimate safety performance if learners cannot distinguish genuine prescribing errors from unusual but clinically justified treatment decisions.

The review consequently adopts an outcome hierarchy comprising knowledge and confidence, demonstrated recognition and management, retention over time, and transfer to clinical or pharmacy practice. These domains should remain analytically distinct because each answers a different educational question.

Immediate assessment establishes what learners can demonstrate under the conditions of a particular exercise.

Delayed reassessment addresses whether the relevant capability persists after the initial learning experience. Practice transfer requires evidence that the capability is demonstrated in authentic professional activity, with sufficient information to determine what was observed, when it occurred, and whether the educational intervention plausibly contributed.

The central research question is: Which pharmacy education interventions improve demonstrated prescribing- and dispensing-error recognition and management, and what evidence establishes retention and transfer into practice beyond immediate test improvement?

A systematic synthesis addressing this question must account for intervention content, learner stage, assessment authenticity, comparator quality, follow-up duration, and study design. Its contribution lies in identifying what the available educational evidence actually measures and determining which conclusions remain unsupported when outcome definitions or assessment conditions differ.

Materials and Methods

Review objectives and eligibility criteria

The review was designed to examine educational interventions intended to improve pharmacy learners' recognition or management of prescribing and dispensing errors. The primary population comprises undergraduate pharmacy students, postgraduate pharmacy trainees, and learners participating in structured pharmacy education. Studies of practising pharmacists are relevant to the intervention evidence only when a defined educational exposure and corresponding learner outcomes can be separated from routine professional activity.

The intervention scope includes simulation-based instruction, electronic medication-order verification, virtual dispensing exercises, case-based teaching, structured feedback, medication-safety training, and other educational activities directly addressing error identification or management. Comparators may include conventional teaching, alternative educational approaches, previous cohorts, baseline assessments, or concurrent control groups.

The primary outcomes are objectively assessed recognition of prescribing or dispensing problems and demonstrated management decisions. Secondary outcomes include knowledge, confidence, reasoning processes, retention, and authentic practice transfer.

Studies were eligible when pharmacy learners received an identifiable educational intervention and the reported outcomes included objective recognition or management of prescribing or dispensing errors, medication-order verification, or closely aligned accuracy-check performance. Studies limited to attitudes, satisfaction, platform description, or clinical tasks outside the defined medication-error domain were excluded from the intervention synthesis.

Intervention evaluations require an identifiable educational exposure and a reported outcome relevant to the review question. Randomized and nonrandomized comparative studies, before-and-after evaluations, and appropriately documented educational intervention studies may contribute according to their designs. Qualitative investigations can inform understanding of learners' reasoning and assessment processes, but do not independently establish comparative intervention effectiveness.

Reviews and methodological publications were used to inform background, terminology, and review procedures but were not counted as primary intervention studies. Multiple reports from the same learner sample or educational experiment were treated as a single study for inclusion and synthesis.

Eligible reports were restricted to the 2017-2025 publication period. This interval was selected to capture contemporary pharmacy education approaches incorporating electronic records, virtual simulation, clinical decision support, and structured performance assessment.

Protocol and registration

This systematic review was conducted and reported in accordance with PRISMA 2020 [8], with search reporting informed by PRISMA-S [9]. The review question, eligibility criteria, outcome hierarchy, and synthesis plan were specified before screening.

The review protocol specified the population, intervention scope, primary and secondary outcomes, study-selection rules, extraction fields, appraisal domains, and synthesis approach and was maintained as project documentation throughout the review.

Prespecified methodological distinctions concerned four areas: the clinical error domain; the educational intervention and comparator; the authenticity of the performance assessment; and the time separating instruction from outcome measurement.

These distinctions are necessary to prevent changes in knowledge, confidence, simulated performance, and workplace behaviour from being treated as equivalent evidence of educational effectiveness.

Information sources and search strategy

PubMed/MEDLINE, Scopus, and ERIC were searched for records published from 1 January 2017 through 31 December 2025. The final search was conducted on 15 January 2026. Searches combined terms relating to pharmacy learners, pharmacy education, medication errors, prescribing errors, dispensing errors, simulation, medication-order verification, medication safety, recognition, management, performance, and retention.

Database-specific Boolean combinations used synonyms and spelling variants for the population, educational intervention, medication-error domain, and performance outcome. Reference lists of relevant reviews and eligible studies were also checked, and DOI and publisher metadata were used to verify bibliographic identity.

Search reporting followed PRISMA-S principles concerning information sources, search dates, limits, record handling, and reproducibility [9].

The combined search and supplementary citation checking yielded 38 unique records for title-and-abstract screening.

Records were normalized by DOI, title, author, and publication year before screening. No duplicate records remained after source consolidation, so all 38 records proceeded to title-and-abstract screening.

Full texts were retrieved for records that appeared to meet the eligibility criteria or could not be resolved at title-and-abstract screening. DOI and publisher metadata were checked before final eligibility decisions.

Study selection and data extraction

Two reviewers independently screened titles and abstracts and then assessed potentially eligible full texts against the prespecified criteria. Disagreements were resolved through discussion and consensus.

Data extraction distinguished study characteristics, educational exposures, comparator arrangements, assessment methods, outcome definitions, and measurement timing.

For each included study, extracted information comprised publication identifier, educational setting, learner level, study design, error domain, intervention content, comparator, assessment format, reported findings, follow-up timing, and design limitations.

One reviewer completed the study-level extraction and a second reviewer checked the extracted fields against the source report. Discrepancies were resolved by returning to the full-text report and reaching consensus.

For delayed assessments, extraction preserved the reported follow-up interval and whether the same competency was reassessed. For practice-transfer outcomes, extraction required an identifiable professional setting, learner activity, observation source, and medication-safety action.

Information not reported by an included study was recorded as not reported rather than inferred from the intervention label or curricular description.

Of the 38 records screened, 32 were excluded at title-and-abstract review. Six reports were assessed in full text. Two were excluded at this stage: one because the outcome fell outside the defined prescribing- or dispensing-error domain and one because the educational task did not evaluate an eligible learner-level error-recognition or management outcome. Four studies were included in the final synthesis.

Screening decisions and full-text exclusion reasons were recorded in a review ledger, and all included reports were reconciled at the study level before extraction and synthesis.

Risk-of-bias assessment

Risk of bias was assessed at study level according to the design and conduct of each educational evaluation, with emphasis on the credibility of inferences about the intervention and measured outcome.

Appraisal domains included allocation or cohort comparability, confounding, deviations from intended educational exposure, missing outcome data, outcome measurement, and selective reporting; RoB 2 principles informed appraisal of randomized designs where applicable [10].

For nonrandomized educational evaluations, particular attention was given to baseline differences between learner groups, prior clinical exposure, changes in curricular conditions, non-equivalent assessment cases, intervention contamination, incomplete follow-up, and selective outcome reporting.

Historical cohort comparisons require special consideration because curricular revisions, changing assessment requirements, and differences in learner preparation may coincide with the educational intervention.

Uncontrolled before-and-after studies also present interpretive difficulties when learners encounter similar assessment material repeatedly. Improvement may reflect the educational intervention, test familiarity, additional learning opportunities, or combinations of these influences.

Self-reported confidence measures require examination of instrument validity and response characteristics. Objective performance assessments require consideration of case construction, scoring criteria, assessor independence, and the extent to which the assessment reproduces the intended professional decision.

Overall judgments were assigned as low, moderate, or serious risk of bias after domain-level assessment, with disagreements resolved by consensus.

Outcome classification and synthesis methods

Outcomes were organized conceptually according to their relationship to the review question and the degree of performance demonstrated.

The first level comprises knowledge and confidence. Knowledge measures indicate recall or understanding of medication-safety information, whereas confidence measures capture learners' perceptions of their capability. The second level comprises demonstrated recognition and management. Recognition includes identifying a prescribing or dispensing discrepancy. Management includes the clinical or operational response selected after recognizing that discrepancy.

These outcomes are further distinguished by error domain. Prescribing-error assessments concern the appropriateness of medication orders. Dispensing-error assessments concern interpretation, selection, preparation, checking, and supply. A study may address both domains, but each reported endpoint requires an identifiable operational definition.

The third level comprises retention. An outcome qualifies as retention evidence only when relevant competence is assessed after a defined interval following the educational exposure.

A delayed assessment of general knowledge does not automatically establish retention of error-recognition performance. Similarly, repeated assessment using an unchanged case requires consideration of test familiarity. The fourth level comprises transfer to clinical or pharmacy practice. This requires observation or documentation of relevant performance in an authentic professional setting. Simulated encounters, however

realistic, remain simulation outcomes unless subsequent workplace performance is separately assessed.

The synthesis framework also distinguishes the immediate educational response from the persistence and applicability of that response. This distinction prevents the synthesis from assigning equal evidentiary weight to substantially different measurements.

Effect estimates should be considered comparable only when the educational exposure, study design, outcome definition, comparator, assessment timing, and available numerical data permit a meaningful comparison.

Where pooling is inappropriate, structured synthesis should preserve study-level direction, magnitude where reported, uncertainty, and methodological limitations. The SWiM reporting guideline provides an appropriate basis for transparently describing synthesis without meta-analysis [11].

Meta-analysis was not undertaken because the included studies differed substantially in educational exposure, comparator design, assessment format, and outcome definition. A structured narrative synthesis therefore compared the direction and scope of findings within prescribing-error recognition, dispensing-error recognition and management, retention, and practice transfer, consistent with SWiM guidance [11].

Certainty-of-evidence assessment, where applicable

Certainty assessment concerns the strength of evidence supporting a particular outcome-level conclusion, taking account of study limitations, consistency, directness, precision, and possible reporting bias.

The distinction between directness and assessment authenticity is particularly important for this review. A well-conducted simulated intervention study may provide direct evidence about simulated performance while offering only indirect evidence concerning actual professional practice.

Likewise, an immediate post-intervention assessment cannot establish long-term retention simply because the assessed competency is relevant to future practice.

The certainty framework therefore requires separate consideration of prescribing-error recognition, dispensing-error recognition and management, delayed retention, and authentic practice transfer.

The PRISMA 2020 explanation and elaboration guidance informs transparent reporting of these assessments and the relationship between individual-study evidence and review conclusions [12].

Confidence in each outcome domain was categorized as high, moderate, low, or very low by considering study limitations, consistency, directness, precision, and the number of contributing studies.

These confidence judgments were applied after synthesis and interpreted separately for simulated performance, delayed retention, and authentic workplace transfer.

Results and Discussion

Study identification and selection

The search identified 38 unique records relevant to pharmacy medication-safety education. All 38 records entered title-and-abstract screening because no duplicate records remained after source consolidation.

Thirty-two records were excluded during title-and-abstract screening. Six reports were retrieved and assessed at full text, and none were unavailable for assessment.

Two full-text reports were excluded: one because the assessed outcome was outside the prespecified medication-error domain and one because the educational task did not measure an eligible learner-level recognition or management outcome. Four studies were included in the final synthesis.

The identification, screening, eligibility assessment, and final inclusion process is presented in **Figure 1** in accordance with the PRISMA 2020 framework.

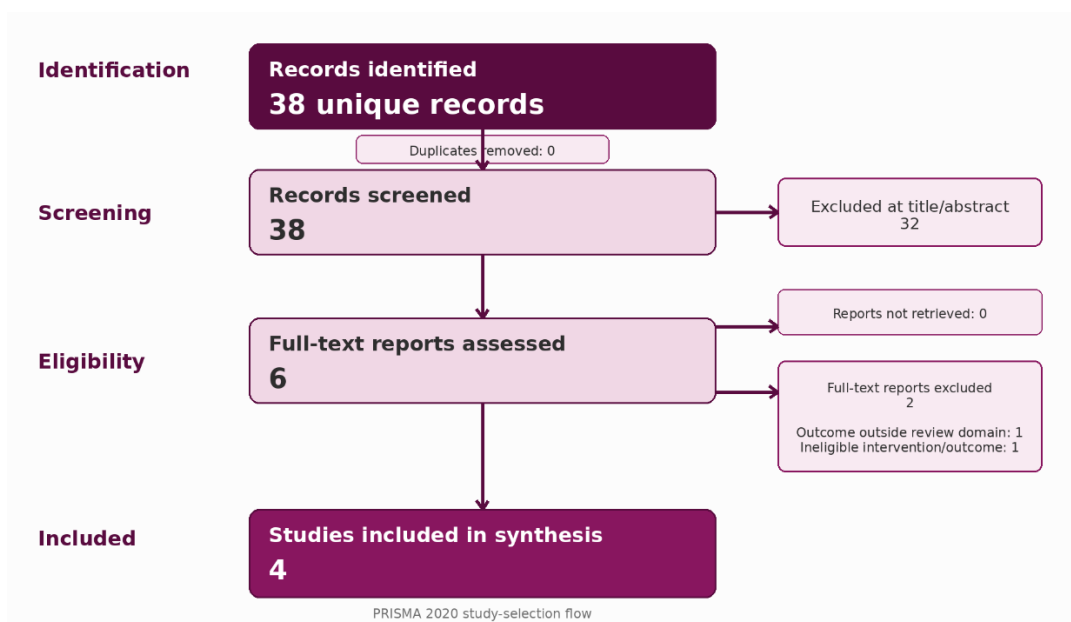


Figure 1. PRISMA 2020 study-selection record for pharmacy error-recognition education

Characteristics of included studies

Four studies met the inclusion criteria and represented distinct pharmacy medication-safety education contexts: a historical-cohort evaluation of inpatient medication-order verification, a repeated simulation study involving clinical decision-support alerts, a quasi-experimental pilot of electronic medication verification, and a between-cohort evaluation of sterile-compounding accuracy checks.

Ives and colleagues examined inpatient medication-order verification using electronic health record technology [13]. Stultz and colleagues assessed responses to

medication-related problems under different clinical decision-support alert conditions [14]. Chan and colleagues studied simulated electronic-record verification among novice pharmacy learners [15].

Wisniewski evaluated teaching and assessment of sterile-compounding accuracy checks in pharmacy students [16]. Together, the four studies addressed objectively assessed medication-order or product-verification performance rather than relying solely on self-reported confidence or satisfaction.

Characteristics of the four included studies are summarized in **Table 1**.

Table 1. Characteristics of included pharmacy medication-safety education studies

Study	Learner population	Educational setting	Design or evidence type	Principal assessed domain
Ives <i>et al.</i> , 2020	PharmD students	Inpatient-order simulation	Historical-cohort comparison	Order verification
Stultz <i>et al.</i> , 2023	Pharmacy students	Simulated order verification	Repeated simulation evaluation	Medication-problem detection and response
Chan <i>et al.</i> , 2025	Second-year students	Simulated electronic records	Quasi-experimental pilot	Verify/reject decisions
Wisniewski, 2023	Pharmacy students	Sterile-compounding laboratory	Between-cohort evaluation	Accuracy-check performance

Note: The four studies constitute the final included study set. Outcomes are reported according to the specific medication-safety task assessed in each investigation.

Educational intervention characteristics

The included interventions varied in educational exposure and assessment design. Three studies focused on prescribing- or medication-order verification using electronic or simulated records, whereas one focused on dispensing-related sterile-compounding accuracy checking.

Ives *et al.* incorporated electronic health record activities into inpatient medication-order verification [13]. Stultz *et al.* used repeated medication-order simulations with and without clinical decision-support alerts [14]. Chan *et al.* evaluated electronic verify/reject decisions [15], and Wisniewski assessed sterile-compounding accuracy-check performance before and after additional teaching and remediation [16].

Across the included studies, the educational tasks required learners to interpret clinical or technical information and make an observable medication-safety decision. Assessment formats nevertheless differed sufficiently to preclude treating the interventions as interchangeable.

All four studies evaluated performance in educational or simulated settings. None used an authentic workplace outcome as the primary measure of intervention effectiveness.

Because intervention content, comparator structure, and outcome definitions differed, findings were synthesized by outcome domain rather than pooled statistically.

The relationship between educational exposure and demonstrated assessment is summarized in **Table 2**.

Table 2. Educational exposure and assessment characteristics of included studies

Educational approach	Included study	Assessment format	Principal endpoint	Interpretation boundary
Electronic-record instruction	Ives <i>et al.</i>	Simulated order processing	Performance and confidence	Historical cohort
Repeated alert-based simulation	Stultz <i>et al.</i>	Medication orders with and without alerts	Appropriate responses	Repeated simulated decisions
Virtual medication verification	Chan <i>et al.</i>	Electronic verify/reject cases	Decision accuracy and confidence	Immediate simulated assessment
Sterile-product accuracy teaching	Wisniewski	Compounding accuracy checks	First-attempt and remediation performance	Specialist technical task

Note: Interpretation boundaries reflect the design and assessment context of each included study.

Effects on prescribing-error recognition

Electronic medication-order verification studies provide direct examples of the distinction between recognizing a problem and selecting an appropriate response.

Ives and colleagues reported improved medication-order processing performance following the introduction of electronic health record activities, compared with the preceding paper-based teaching cohort [13]. The

historical comparison introduces uncertainty concerning the independent contribution of the electronic-record platform.

Stultz and colleagues reported that responses to medication problems differed according to the presence and preceding frequency of clinical decision-support alerts [14]. Repeated simulations were associated with improved responses, including cases without alerts. The

findings identify alert dependence as an educationally relevant concern, but remain specific to simulated medication-order decisions.

Chan and colleagues examined novice learners' verification decisions using simulated electronic medication records [15]. The study illustrates the importance of evaluating whether learners appropriately accept safe orders as well as reject problematic ones.

Across the three prescribing-focused studies, improvements were demonstrated within simulated educational tasks rather than authentic practice settings. The studies therefore provide evidence about medication-order recognition and response under assessment conditions, with more limited directness for routine professional practice.

The direction of findings generally favored structured electronic or simulation-based practice, but heterogeneity in design and outcome definition precluded a pooled comparative estimate.

Effects on dispensing-error recognition and management

Dispensing-related educational studies address prescription processing, product selection, technical accuracy, and verification of prepared products. These tasks differ in their measurement requirements.

Wisniewski reported that additional teaching and practice did not improve first-attempt sterile-compounding accuracy-check performance in the later cohort, although remediation performance improved [16]. The authors identified pandemic-related restrictions on practical teaching as a possible contributing factor. This contrary finding demonstrates why greater educational exposure should not be assumed to produce better initial performance.

No second included study directly evaluated dispensing-error recognition or dispensing-management performance. This outcome domain was therefore represented by a single specialist technical assessment.

Wisniewski's findings suggest that remediation can improve subsequent accuracy-check performance even when first-attempt performance does not improve [16],

but the result should not be generalized to all dispensing activities or prescribing decisions.

Evidence for dispensing-error recognition and management was consequently limited and task-specific.

Retention of learning

Retention requires reassessment after the initial educational exposure, with the interval and assessed competency explicitly identified.

None of the four included studies measured long-term retention after a prespecified delayed follow-up interval. Stultz *et al.* incorporated repeated simulated assessments [14], and Wisniewski reported remediation performance [16], but these designs primarily reflect repeated or short-term performance rather than durable retention over an extended interval.

Long-term retention of prescribing- and dispensing-error recognition and management skills therefore remained insufficiently studied within the included evidence.

Transfer to clinical and pharmacy practice

Transfer is the most demanding outcome in the proposed hierarchy because it requires evidence of performance beyond the instructional environment.

All four included studies assessed learners in educational or simulated environments. None reported independently assessed medication-safety performance during authentic clinical or pharmacy practice.

An authentic assessment must identify the practice setting, learner responsibility, observation or data source, and the medication-safety action performed. Such evidence may include supervised medication verification, documented discrepancy identification, clinically appropriate escalation, or dispensing accuracy under routine professional conditions.

Accordingly, authentic practice transfer could not be evaluated from the included studies and remains an important outcome for future educational research.

Table 3 summarizes the distinction between immediate or repeated performance, delayed retention, and authentic practice transfer across the included studies.

Table 3. Retention and practice-transfer evidence among included studies

Included study	Measured competency	Assessment timing	Retention evidence	Authentic practice transfer
Ives <i>et al.</i>	Simulated inpatient order processing	Following educational activity	No delayed follow-up reported	Simulation only; no workplace outcome

Stultz <i>et al.</i>	Responses to medication problems with and without alerts	Repeated simulated assessments	Repeated performance; no extended delayed follow-up	Simulation only; no workplace outcome
Chan <i>et al.</i>	Simulated medication verification	Immediate educational assessment	No delayed follow-up reported	Simulation only; no workplace outcome
Wisniewski	Sterile-product accuracy checking	Initial and remediation assessments	Remediation performance; no extended delayed follow-up	Educational laboratory; no workplace outcome

Note: Repeated assessments and remediation were classified separately from long-term retention. No included study measured authentic workplace transfer.

Risk of bias and certainty of evidence

Study-level appraisal identified moderate risk of bias for Ives *et al.*, Stultz *et al.*, and Chan *et al.*, and serious risk of bias for Wisniewski. No included study was judged to have low overall risk of bias.

The principal concerns were historical-cohort confounding, repeated exposure and test familiarity,

immediate simulated outcome measurement, and between-cohort differences in teaching conditions. These limitations reduced confidence in causal interpretation while still permitting task-specific educational conclusions.

Study-level appraisal judgments and their contribution to confidence in the synthesis are summarized in **Table 4**.

Table 4. Study-level risk-of-bias appraisal and confidence contribution

Included study	Design/appraisal focus	Principal methodological concern	Overall risk-of-bias judgment	Confidence contribution
Ives <i>et al.</i>	Historical-cohort comparison	Cohort differences and confounding	Moderate	Low
Stultz <i>et al.</i>	Repeated simulation evaluation	Repeated exposure and test familiarity	Moderate	Low
Chan <i>et al.</i>	Quasi-experimental pilot	Immediate simulated outcome measurement	Moderate	Low
Wisniewski	Between-cohort evaluation	Teaching-condition and cohort differences	Serious	Very low

Note: Overall confidence was low for prescribing-error recognition and very low for dispensing-error recognition and management, long-term retention, and workplace transfer because the evidence base was small, heterogeneous, and predominantly simulation-based.

Interpretation of intervention effects

This systematic review identified four educational studies directly relevant to pharmacy learners' recognition or management of prescribing and dispensing errors. The evidence supports the value of electronic-record and simulation-based activities for selected medication-safety decisions, while also showing that conclusions depend strongly on the task, comparator, and assessment conditions.

Electronic-record simulations allow medication problems to be embedded within clinical information, requiring learners to identify relevant cues and make therapeutic judgments. Alert-based studies demonstrate that the presence and reliability of decision support can influence those judgments. An assessment based exclusively on correctly responding to alerts may overlook difficulties detecting medication problems when no alert appears.

The contrasting sterile-compounding findings also show that educational exposure and assessed improvement do

not follow a uniform relationship. Differences in practical training conditions, assessment opportunities, and remediation may alter observed performance.

Practice-level evidence further establishes why educational effectiveness matters beyond the classroom. Jaam and colleagues reviewed pharmacist-led education for healthcare providers and its relationship with medication-error outcomes [17]. Reviews of medication errors in ambulatory and perioperative settings identify additional clinical circumstances in which error prevention and professional intervention are important [18, 19]. These studies provide contextual evidence concerning medication safety, although clinician-level intervention results cannot be transferred directly to pharmacy learners.

Clinical decision-support development adds another consideration. Graafsma and colleagues reviewed artificial intelligence approaches intended to optimize medication alerts [20]. As such systems evolve, pharmacy education must account for both the

information provided by digital tools and the learner's ability to recognize problems independently. The educational implications are interpretive; the review does not establish an effect of AI-supported instruction on learner performance.

Educational design implications

Educational activities should align the intended competency, instructional exposure, and assessment task. Where the objective is prescribing-error recognition, learners require opportunities to identify clinically meaningful problems in medication orders and justify the resulting decisions. Dispensing-error education additionally requires accurate prescription interpretation, product checking, and appropriate corrective action.

Structured feedback is relevant when learners must understand why an apparent discrepancy is clinically important and why a particular response is appropriate. The timing of feedback, the opportunity to reconsider an incorrect decision, and reassessment using different clinical cases are potential design considerations requiring direct evaluation.

Medication reconciliation simulation provides an example of aligning instruction with a defined professional task. Komperda and Lempicki reported differences in simulated medication-reconciliation performance across teaching arrangements [21]. The assessed activity involved obtaining an accurate medication list and identifying and resolving discrepancies; its relevance to prescribing-error education depends on the particular endpoint under consideration.

Longitudinal assessment should retain competency specificity. Ray and colleagues investigated students' retention of computer-use skills during simulated patient encounters [22]. This illustrates a delayed assessment approach without demonstrating retained medication-error recognition.

Targeted clinical problem-solving instruction may provide another approach for learners experiencing difficulty with therapeutic decisions. Rivkin and Patel evaluated such instruction and reported improvement on a pre-practice competency assessment, while improvement was not observed across every broader assessment outcome [23]. The distinction reinforces the importance of examining task-specific and general assessment results separately.

Entrustable professional activities-based objective structured clinical examinations offer a complementary means of aligning educational assessment with professional responsibilities [24]. Their use in medication-error education would require relevant cases, transparent scoring criteria, and assessment of the clinical decisions that the intended professional activity demands.

Limitations of the evidence

This review has several limitations. Only four studies met the eligibility criteria, all evaluated learners in educational or simulated settings, and none measured authentic workplace transfer. The predominance of nonrandomized designs and heterogeneous assessments limited causal inference and precluded meta-analysis.

The included interventions differed in learner preparation, assessment format, clinical complexity, comparator design, and timing. These differences reduce comparability and require study-specific interpretation rather than a single estimate of educational effectiveness. Historical-cohort comparisons are vulnerable to changes in curricular conditions. Repeated simulations may be influenced by previous exposure to similar cases. Self-reported confidence and satisfaction measure perceptions rather than independently demonstrated error recognition.

Retention evidence was limited because none of the included studies incorporated an extended delayed follow-up specifically testing prescribing- or dispensing-error recognition. The absence of workplace outcomes likewise limits conclusions about transfer from educational performance to routine practice.

The synthesis therefore emphasizes demonstrated task performance and preserves a clear distinction between immediate simulation outcomes, durable retention, and authentic practice behaviour.

Implications for future research

Future educational investigations should specify the medication-error categories embedded in assessment cases, the clinical information available to learners, and the criteria used to determine appropriate recognition and management.

Comparative studies would benefit from equivalent assessment cases, transparent comparator descriptions, and independent scoring wherever feasible. Repeated assessments should use appropriately varied scenarios so

that gains can be interpreted in relation to the underlying competence.

Delayed follow-up should establish whether learners retain recognition and management skills after the initial intervention. Studies examining workplace transfer should document actual medication-related decisions in supervised practice, including the observation method and the learner's responsibility.

Evaluation of electronic clinical decision support should include problems both with and without alerts. This would clarify whether learners can identify medication problems independently while using technological assistance appropriately.

Research should also report contrary and null findings alongside improvements. Such reporting is essential for identifying which educational components contribute to performance under particular conditions and which effects remain uncertain.

Conclusion

This systematic review found that simulation, electronic medication-order verification, and structured accuracy-check activities can improve selected medication-safety performance outcomes in pharmacy learners, although effects varied by task and study design.

Demonstrated error recognition and appropriate management should be distinguished from knowledge and confidence. Delayed reassessment is necessary to establish retention, while authentic workplace observation is required to evaluate transfer into practice. The evidence base remains small and methodologically heterogeneous, with limited long-term retention data and no direct evidence of authentic workplace transfer. More rigorous comparative studies with delayed reassessment and practice-based outcomes are needed.

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